

Effective use of sediment quality guidelines 1: Which guideline is right for me?

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Managing Ecological Risk at
Contaminated Sediment Sites

Two Families of Approaches

- Empirically-Derived approaches
 - Biological:chemical correlative
 - Can help to answer the question, “Would we predict this sediment to be toxic?”
- Equilibrium Partitioning (EqP) Approach
 - Theoretically derived from partitioning theory.
 - Can help answer the question, "Can this contaminant, at this concentration, in this sediment, contribute to toxicity?"

Proud Parent of a Sediment
Quality Guideline

KAPPA KAPPA GAMMA
UNIVERSITY OF TULSA

DOOGEE



Honk If You Love
Organic Carbon!

AUTO SALES
BRWICK R.I.

If it Aint Empirically Derived
It's Just Theory!



ND



• Rhode Island

SE-60

• Ocean State

A close-up photograph of the rear of a teal-colored vehicle, likely a truck or SUV. The focus is on the black plastic bumper, which has a white rectangular sticker with blue text. To the left of the bumper is a rectangular taillight. Below the bumper, a black mudflap is visible. The vehicle is parked on a dark asphalt surface, and a patch of green grass is visible in the upper left corner.

It's the Porewater Stupid!

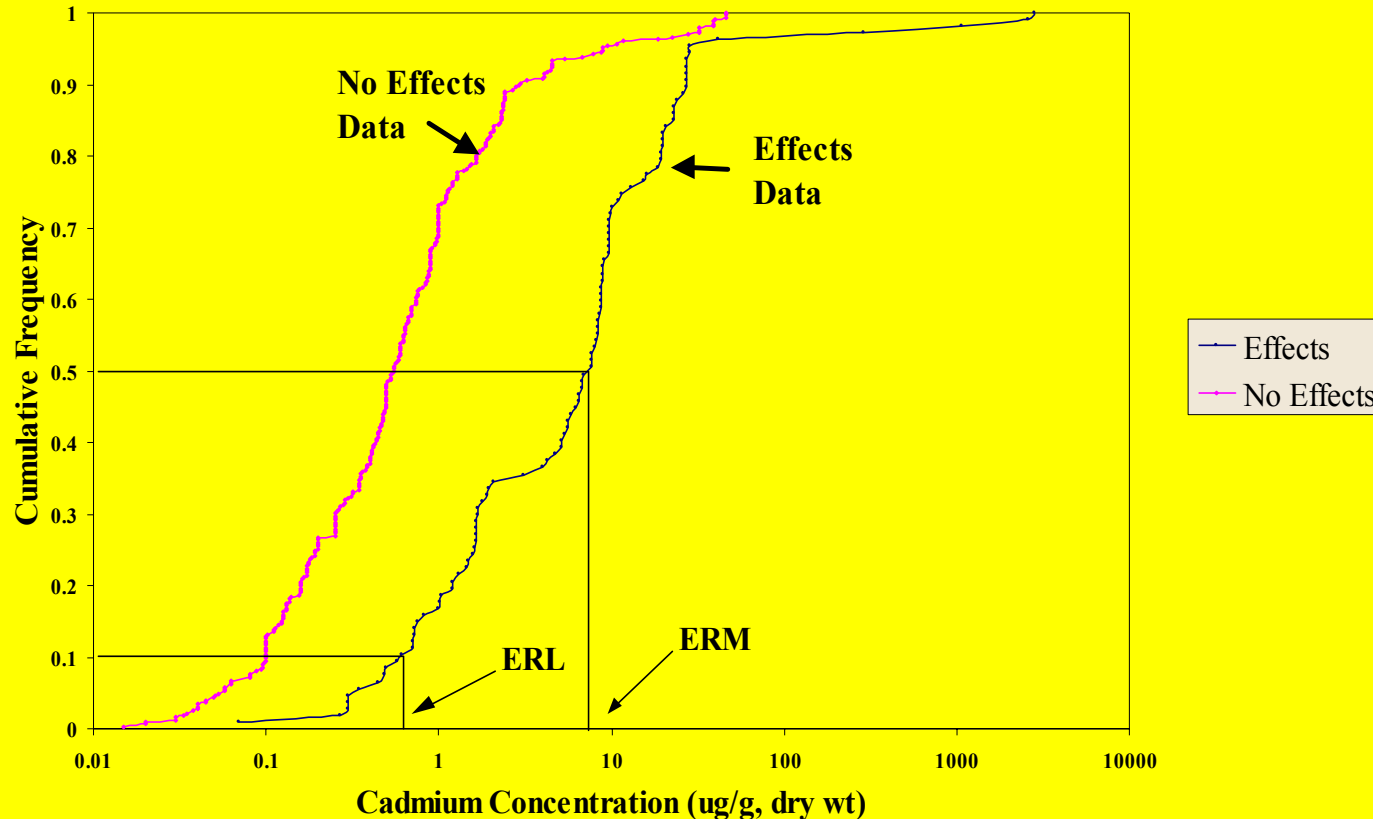
What I Hope to Do Today

- Introduce the “families” of SQGs.
- Show how cadmium guidelines are derived using approaches from both families.
- Show how the derivation influences the appropriate uses of the guidelines.
- Show that the “families” should be used together.
- Entreat you never to make important decisions based on chemistry alone.

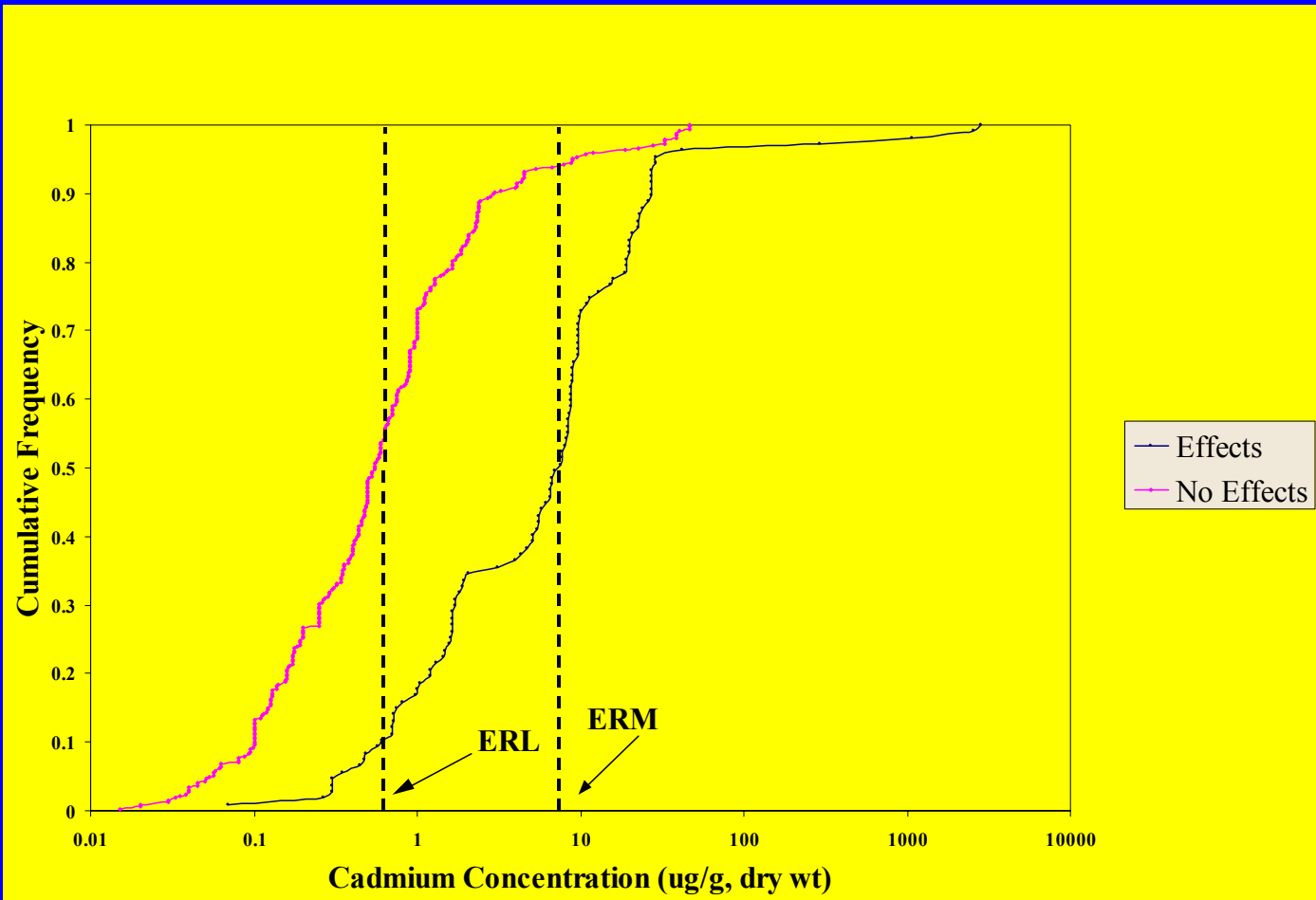
Empirically-Derived Approaches

- Effects Approach:
 - ERL = Effects Range Low,
 - ERM = Effects Range Median.
- Effects Level Approach:
 - TEL = Threshold Effects Level,
 - PEL = Probable Effects Level
- Apparent Effects Threshold (AET)
- Screening Level Concentrations (SLC)

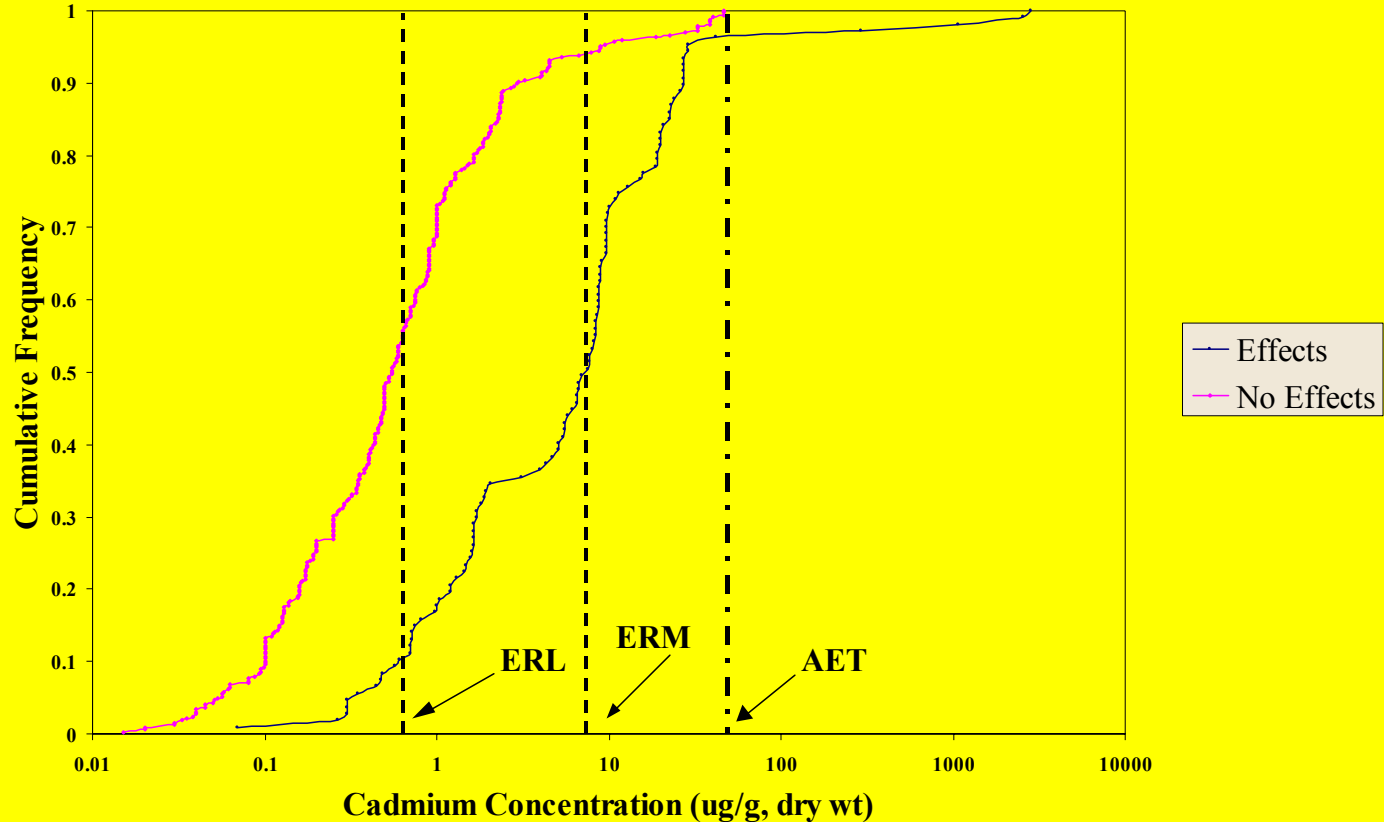
Cumulative Frequency of Cadmium Concentration in BEDS Data Base: Derivation of ERL and ERM



Cumulative Frequency of Cadmium Concentration in BEDS Data Base: Effect/Noeffect relative to ERL and ERM



Cumulative Frequency of Cadmium Concentration in BEDS Data Base: Effect/Noeffect relative to AET



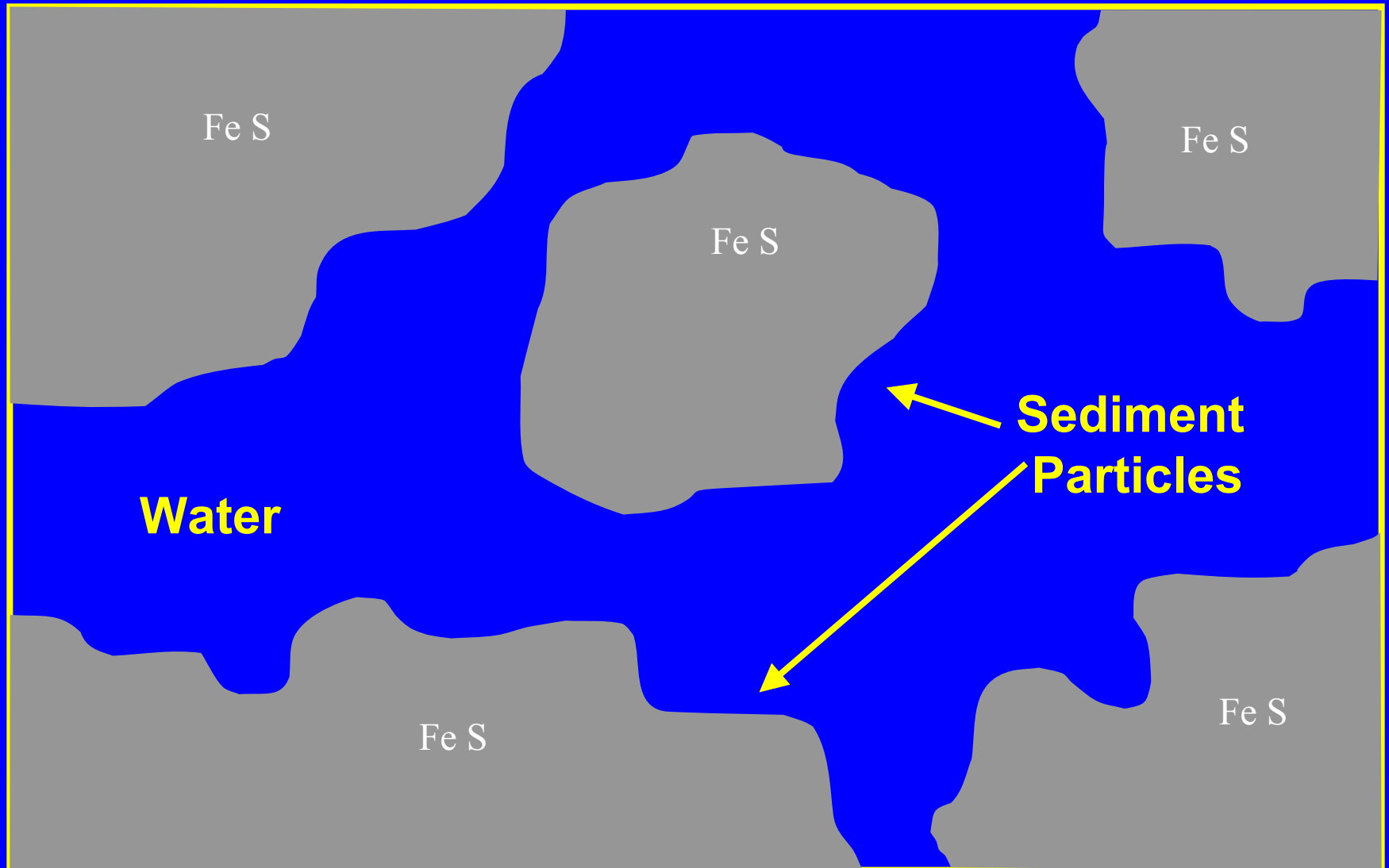
Conclusions: Empirically-Derived Guidelines

- Empirically-derived methods can be used as screening methods in the prediction of sediment toxicity.
- Exceedance of a guideline does not imply that the compound exceeding the guideline is the cause of observed toxicity.

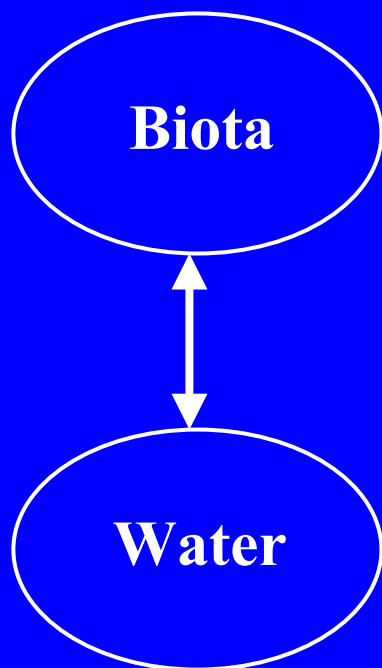
Equilibrium Partitioning Approaches

- Organics
 - Interstitial Water Toxic Units (IWTUs)
 - Total Organic Carbon (TOC)
- Metals
 - Interstitial Water Toxic Units (IWTUs)
 - Acid Volatile Sulfide (AVS)
 - Simultaneously Extracted metal (SEM)

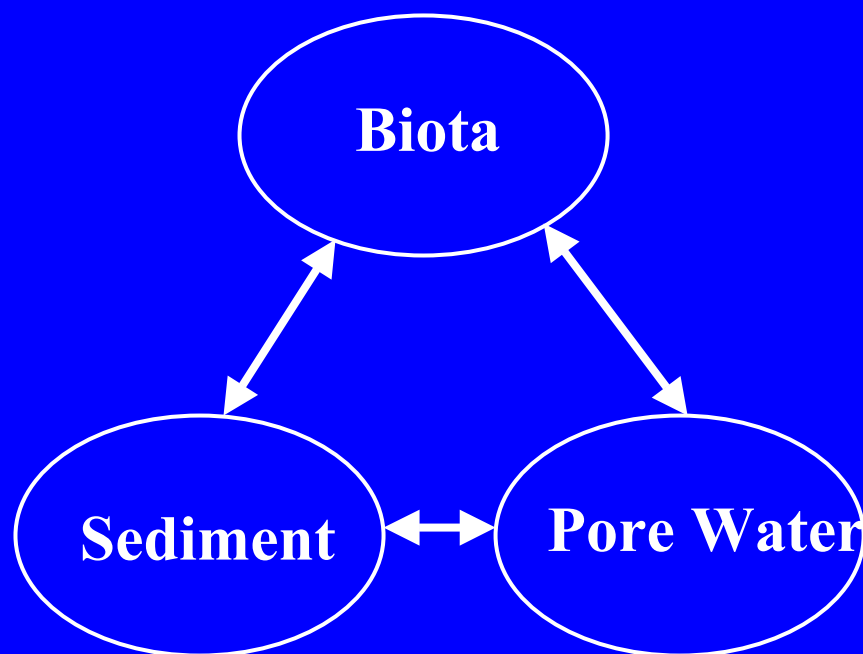
Metals in Sediment and Water
No Metal Contamination
No Biological Effects Due to Metals



Conceptual Models of Chemical Exposure

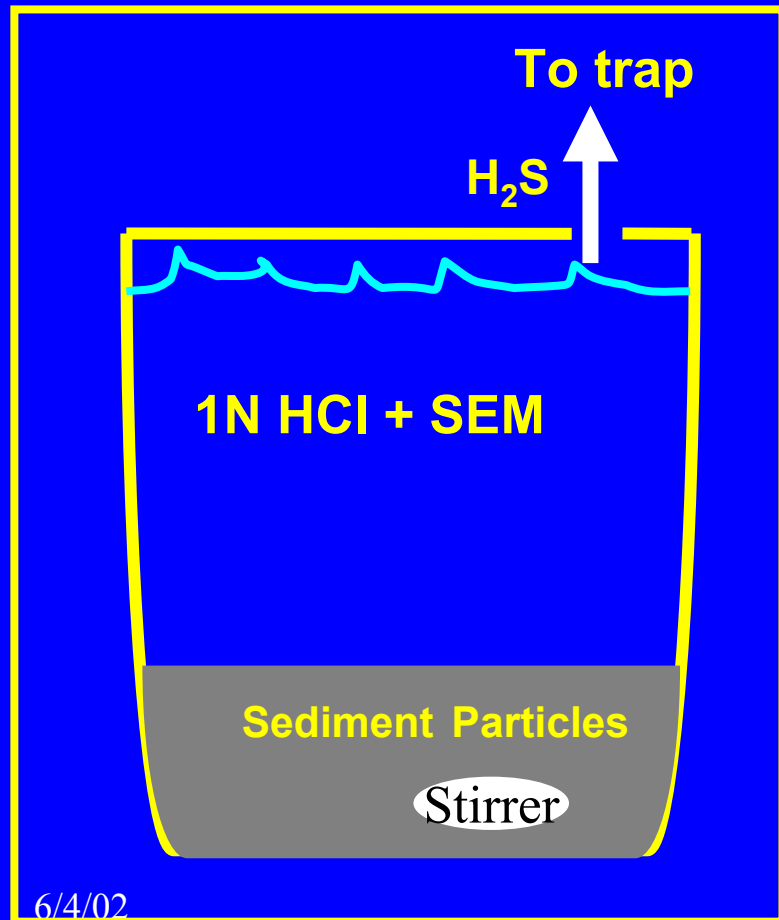


Water-Only



Sediment
“Equilibrium Partitioning”

AVS and SEM Defined



AVS (Acid Volatile Sulfide)

- Produced by bacterial breakdown of organic material
- Iron Sulfide + Manganese Sulfide + Metal Sulfides
- Varies with temperature and depth (lowest in early spring, highest in summer, increases with depth)

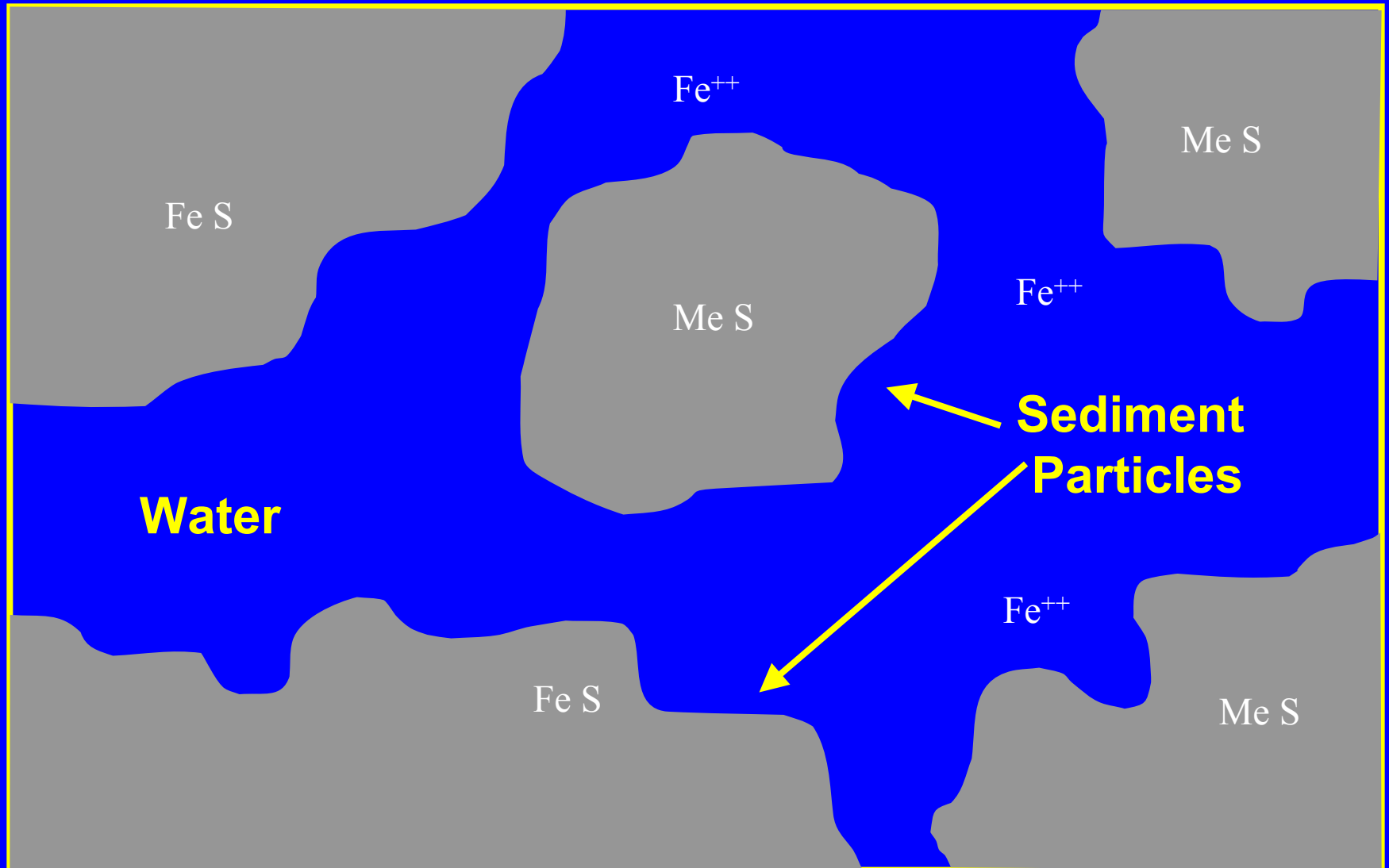
SEM (Simultaneously Extracted Metal)

- Cadmium, Copper, Lead, Nickel, Silver, and Zinc
- Metals extracted during AVS procedure.
- Less than "total metals".

Metals in Sediment and Water

$$AVS \geq SEM[Cd+Cu+Pb+Ni+Zn+Ag/2]$$

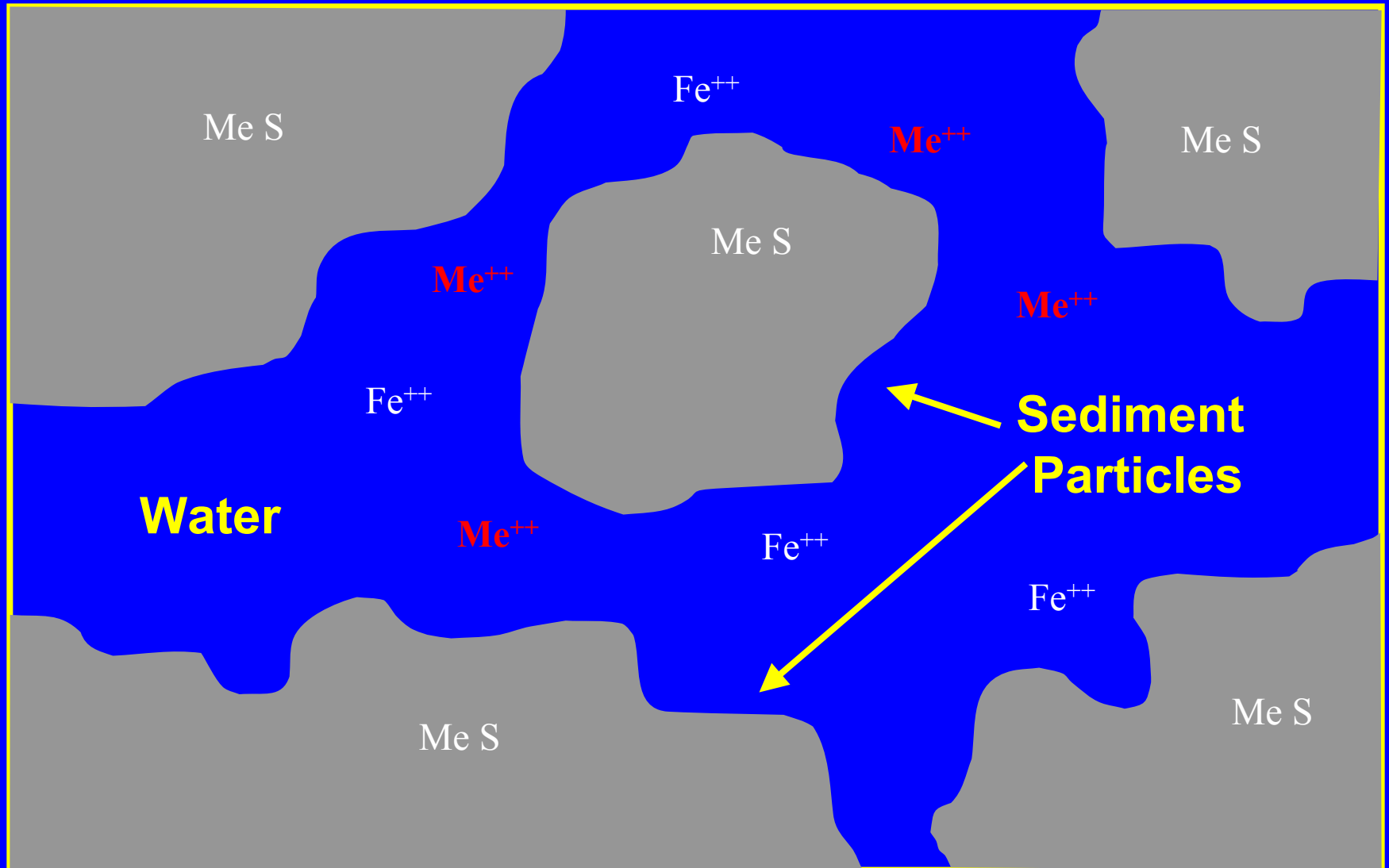
No Biological Effects Due to Metals



Metals in Sediment and Water

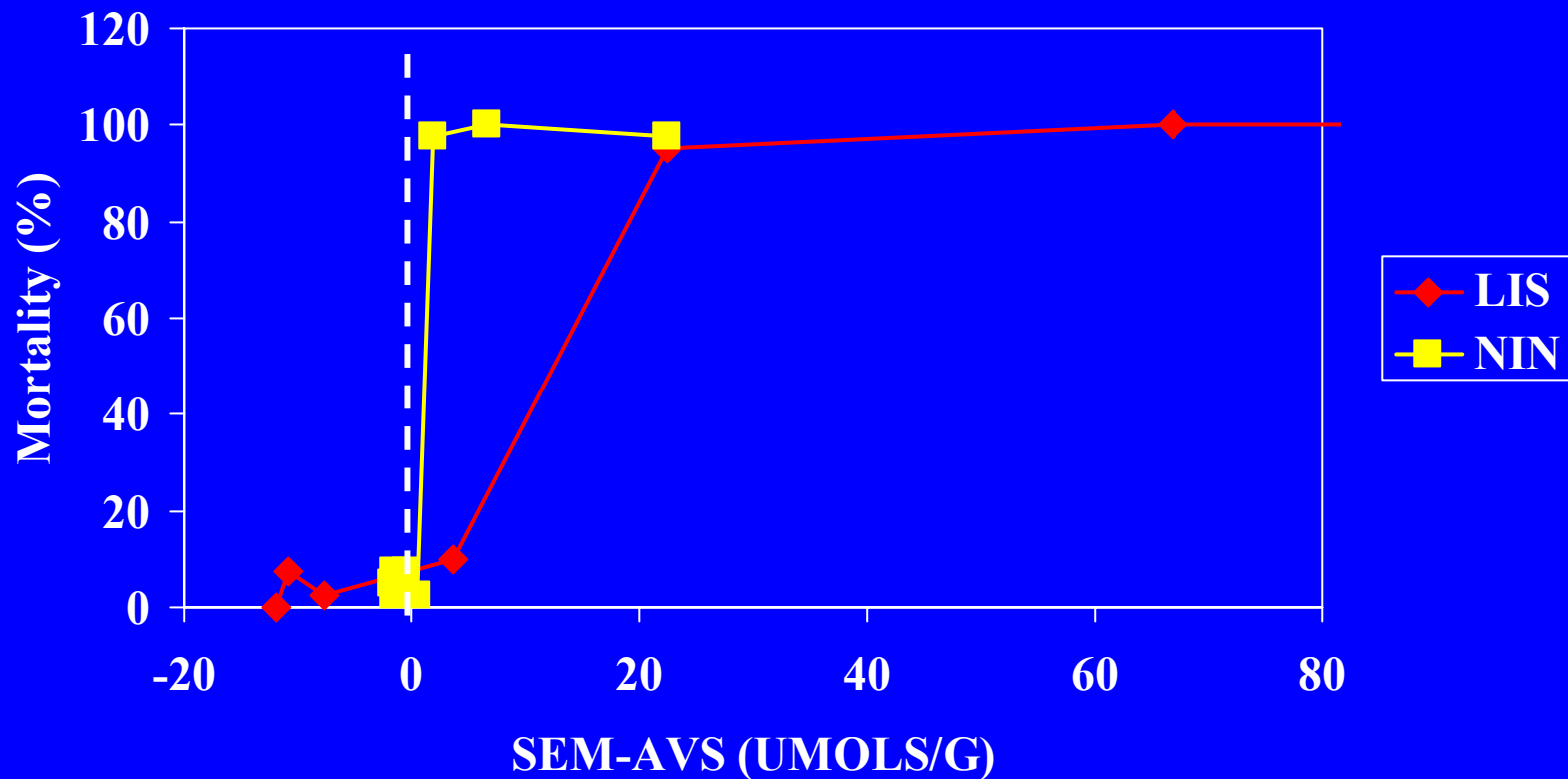
$$AVS < SEM[Cd+Cu+Pb+Ni+Zn+Ag/2]$$

Possible Biological Effects Due to Metals



Mortality vs. SEM-AVS

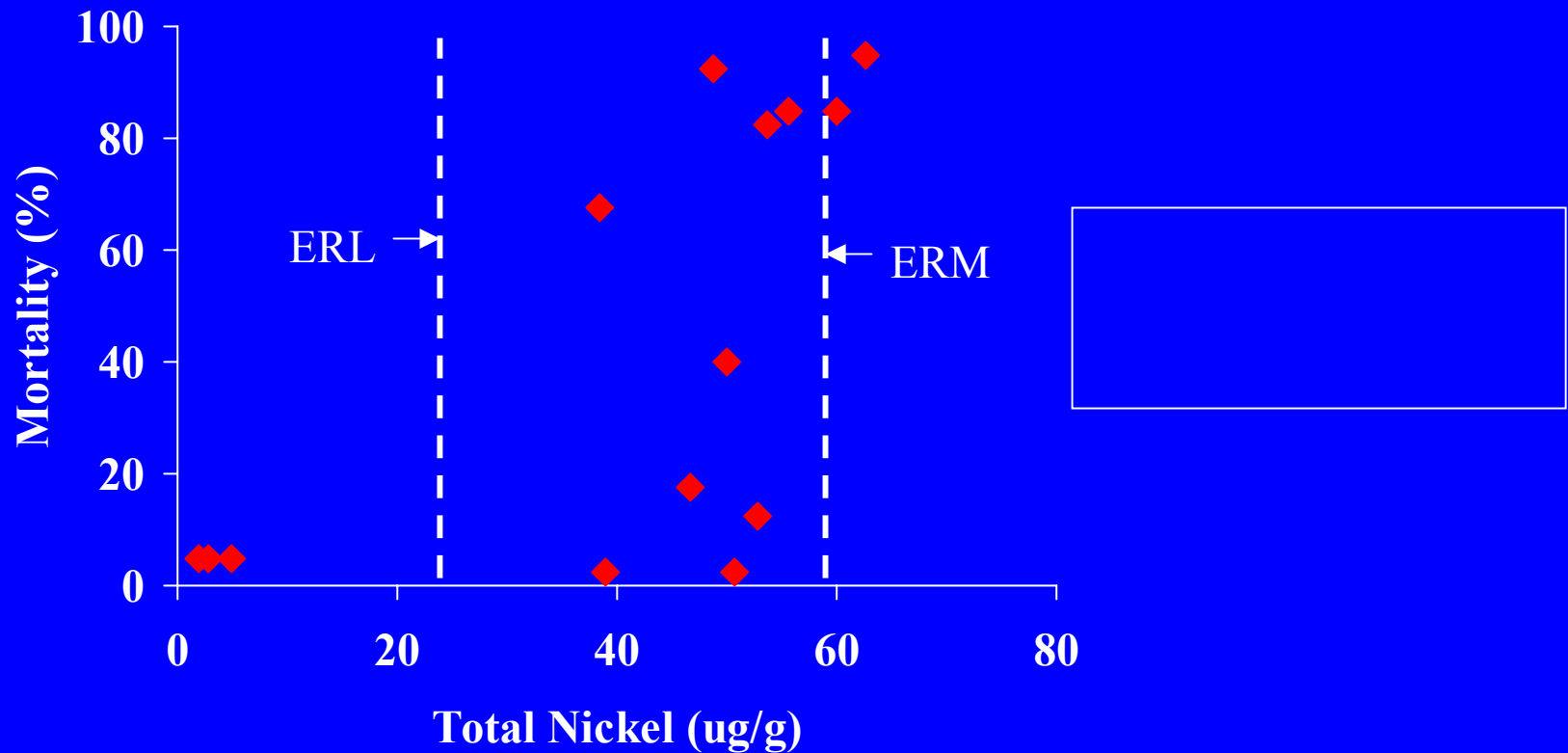
Nickel-Spiked Sediments



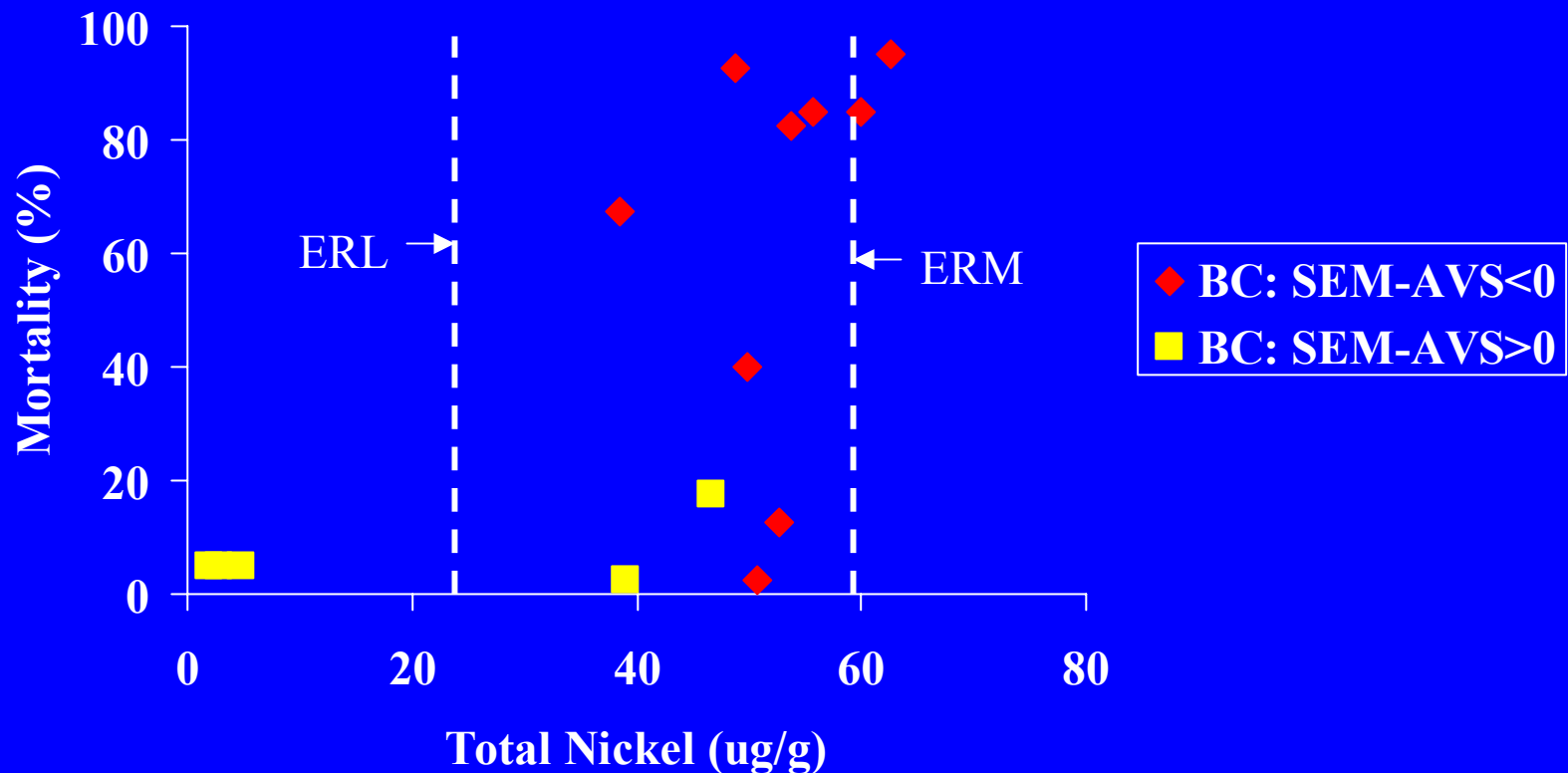
Conclusions: EqP Guidelines

- EqP-generated guidelines cannot predict lack of toxicity in mixed contaminant situations where contaminants have different modes of action.
- IW is useful for predicting the toxicity of both metals and organics in sediments.
- TOC normalization reduces the variation in predicting the toxicity of organic compounds.
- AVS normalization allows the prediction of lack of toxicity from metals in sediments.
- Exceedance of an EqP guideline implies that the compound exceeding the guideline has the potential to be the cause of observed toxicity.

Mortality vs. Nickel from a site where metals are not causing the toxicity: Compared to ERL and ERM for Nickel



Mortality vs. Nickel from a site where metals are not causing the toxicity: Using ERL and ERM and SEM-AVS



Overall Conclusions (1)

- Empirically-derived methods best for predicting, "Will this sediment be toxic?"
- EqP-derived methods are best for answering, "Will this compound contribute to toxicity in this sediment?"
- E-D and EqP guidelines may be similar in some cases, but there are critical differences.
- The most information is gained when the methods are used together.

Overall Conclusions (2)

- Use SQGs together.
- Measure TOC and grain size, they are cheap.
- Preferably do dry wt chemistry, SEM and AVS.
- Definitely measure AVS and SEM if metals guidelines are exceeded and it is important to know if metals are causing toxicity.
- Predict aquatic life effects using empirically-derived and available EqP tools.

Most Important Messages

- NEVER make important decisions based on chemistry alone.
- Always use the right guidelines.

VC-610

• Ocean State •

JUL

**Smart Sediment Assessors
Do It Both Ways!**



Don't like my guideline?
Dial 1-800-Eat-Dirt!

Most Important Message

- Measure TOC and grain size, they are cheap.
- Preferably, do dry wt chemistry, AVS and SEM.
- Definitely, measure AVS and SEM if metals guidelines (ERL/TEL) are exceeded and it is important to know if metals are causing toxicity.
- Predict aquatic life effects using empirically-derived and available EqP tools.
- NEVER make important decisions based on chemistry alone.

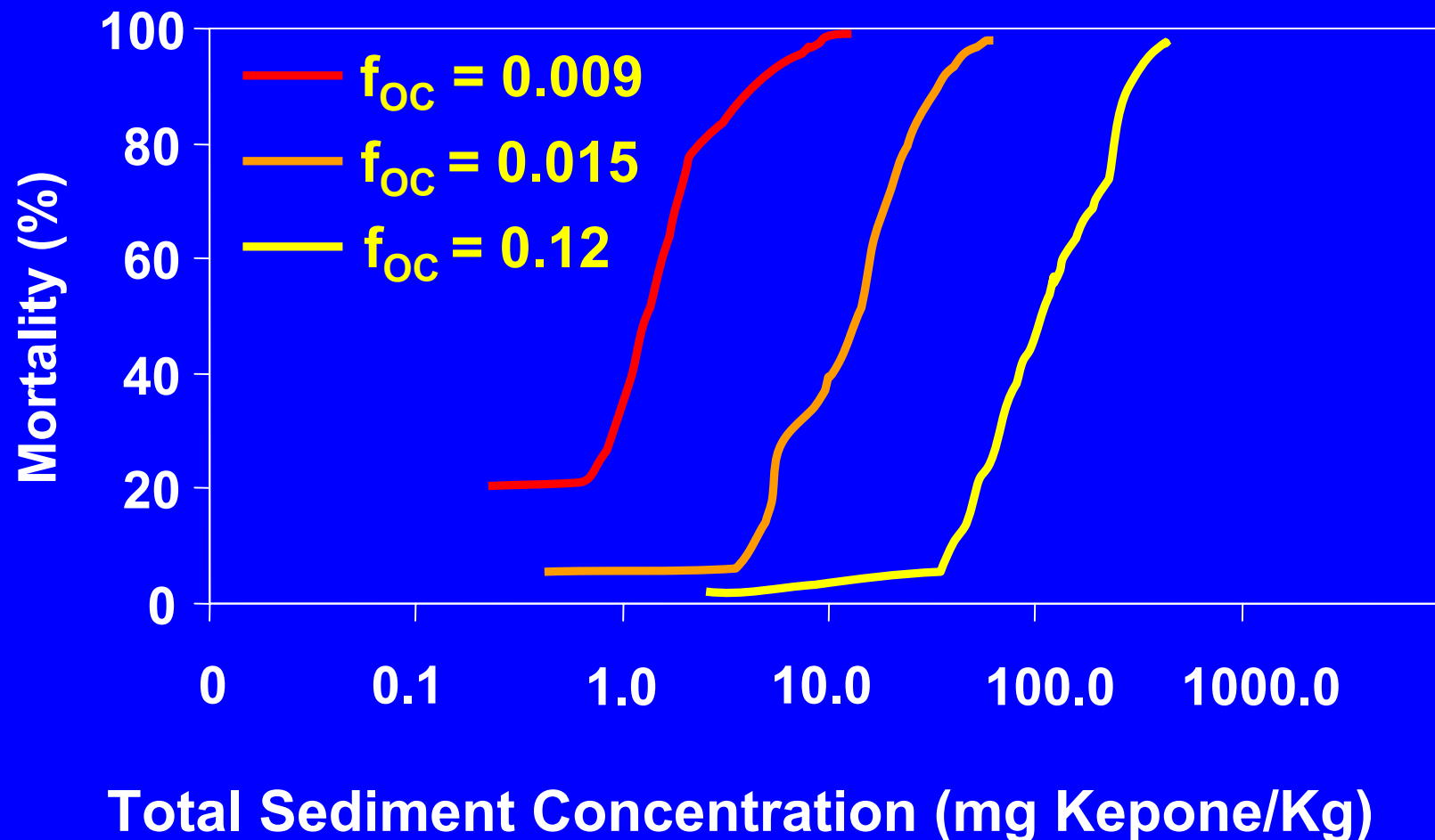
You Might Wait Before You Do AVS and SEM If:

- You are very, very short of money.
- Have lots and lots of samples.
- Are in a screening mode.
- Do not care what is causing toxicity at the site.
- Have no reason to believe that metals are a problem.

You Want To DO AVS and SEM Right Away If:

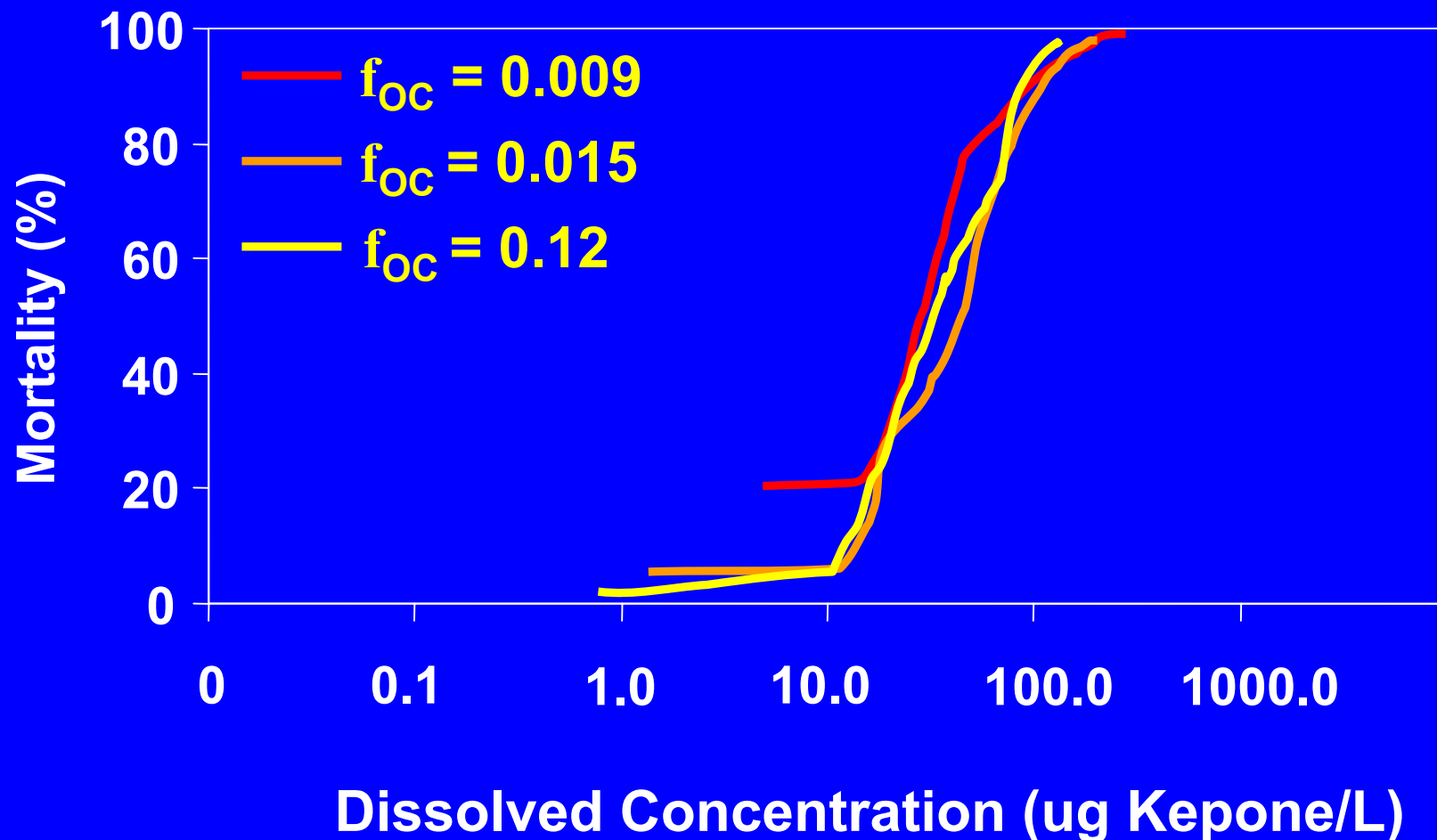
- You violate any metals guidelines.
- You suspect that metals are a problem at the site.
- You have a smaller amount of samples.
- You care what is causing toxicity at the site.
- You want to establish cleanup limits for the site.

Mortality vs. Dry Wt Kepone is Sediment-Specific



(Adams et al. 1985)

Mortality vs. IW Kepone is Not Sediment-Specific



(Adams et al. 1985)

Predict Dissolved Concentration

Bioavailable Concentration

$$[\text{Kepone}]_{\text{Dissolved}} = \frac{[\text{Kepone}]_{\text{Particulate}}}{K_{\text{OC}} * f_{\text{OC}}}$$

Difficult to Measure

**Can be Calculated
or Measured**

Easy to Measure

- Initially there were no chemistry benchmarks, and the first empirical guidelines were greeted with great enthusiasm.

- When the Equilibrium Partitioning (EqP) guidelines came along, some may have been a little excessive in pointing out some of the problems with using dry weight normalization.

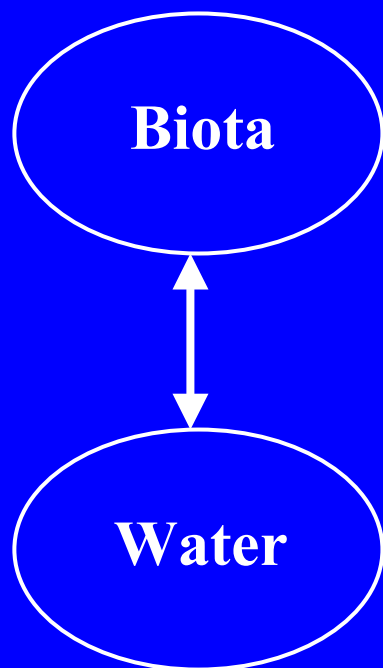
- This led to a backlash from the empirical school...

- Then things really started to get ugly...

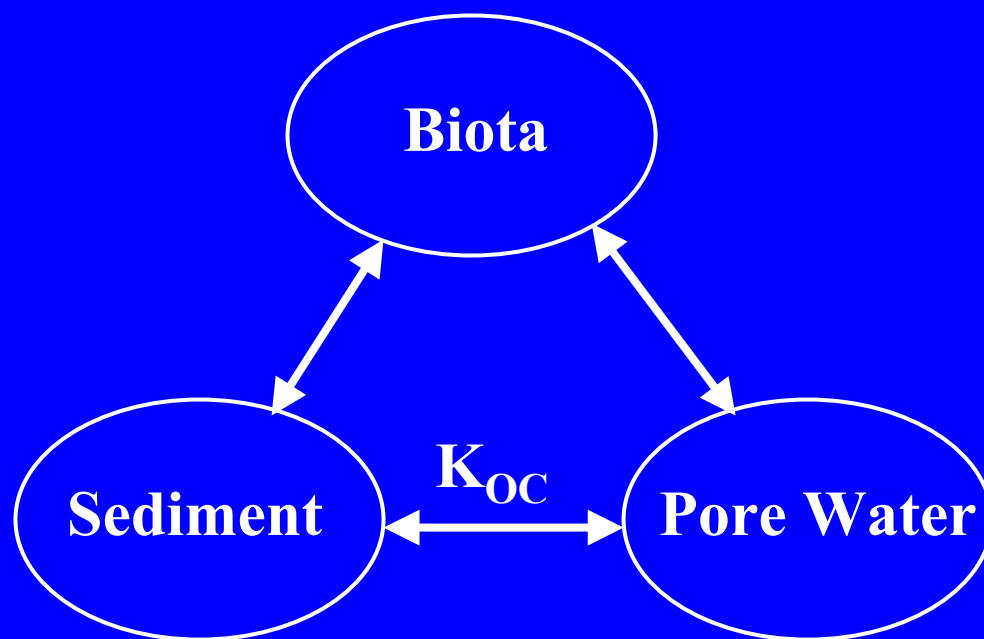
- The best way to use chemistry data is to use both empirical and equilibrium partitioning approaches.

- Nowadays the big question in some camps is, “Should we use SQGs at all?”
- Used properly, with an eye to how they were derived, they can be very useful.

Conceptual Models of Chemical Exposure: Nonionic Organics

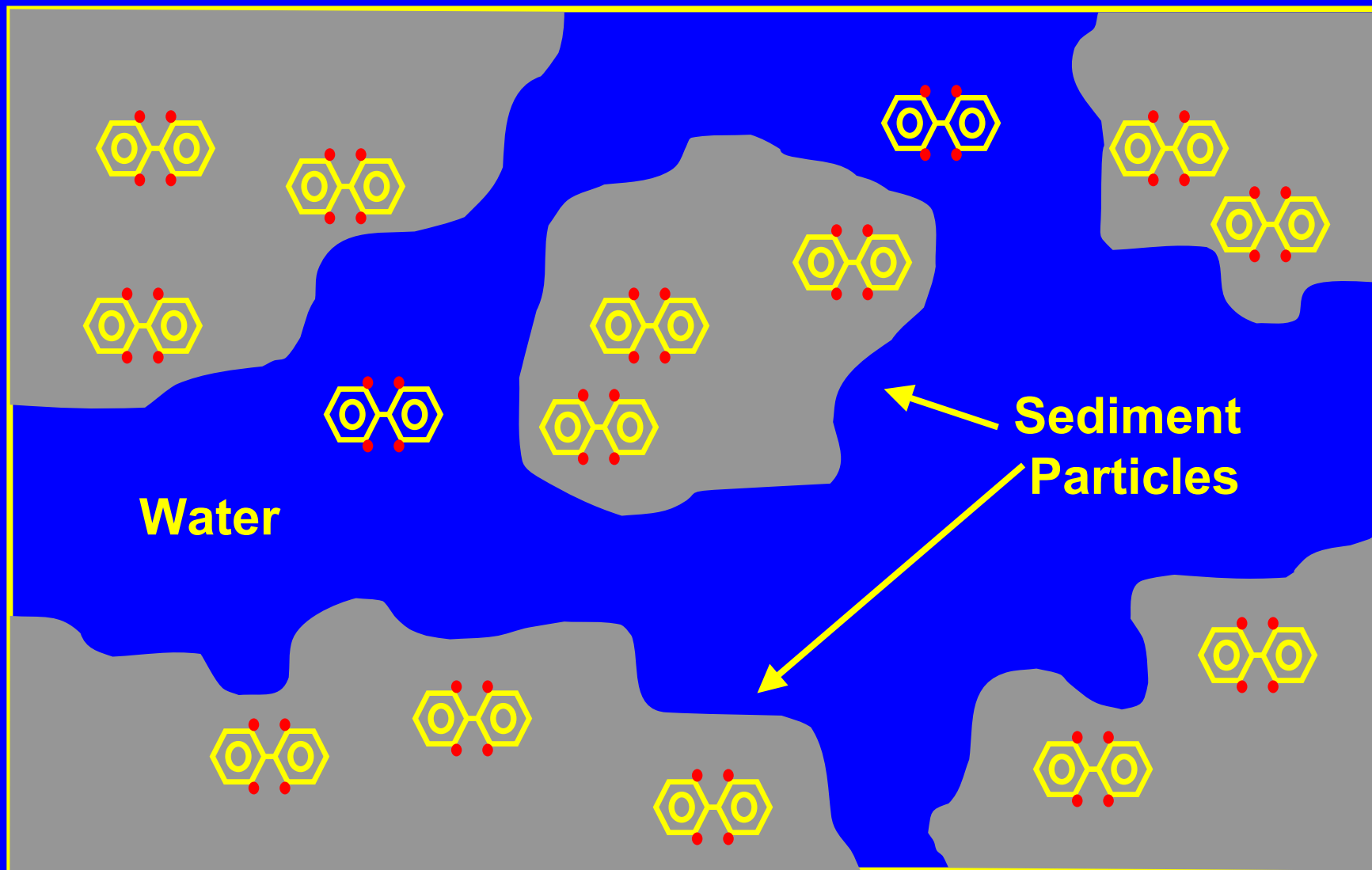


Water-Only

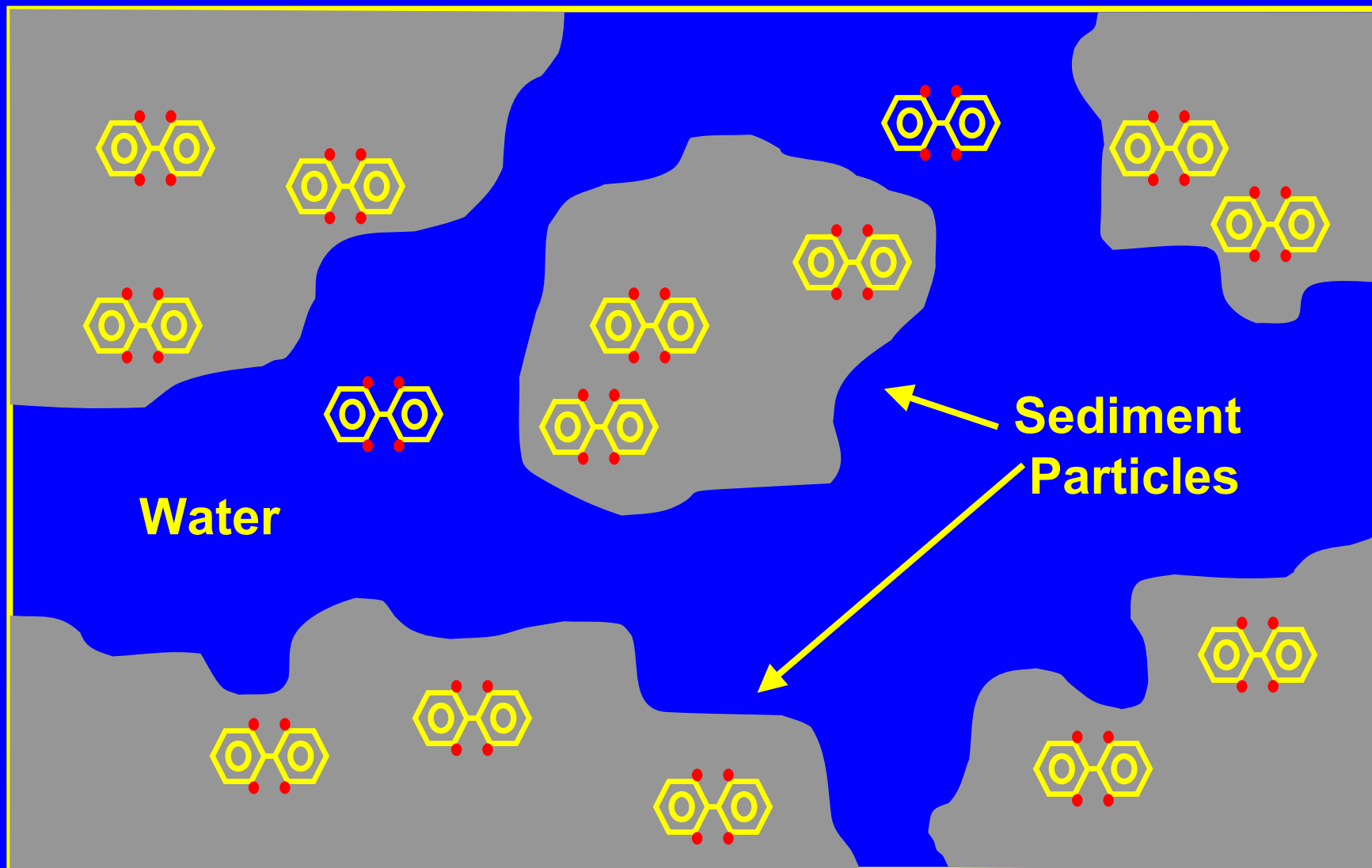


**Sediment
“Equilibrium Partitioning”**

PCBs in Sediment and Water



$$K_{oc} = [Water]/[Organic Carbon]$$



EqP-Derived Guidelines

- If the dissolved concentration is substituted with a known water-only effects concentration for chemical_x (e.g., FCV_x):

$$[\text{FCV}_x]_{\text{Water}} * K_{\text{OC}} = [\text{SQG}_x]_{\text{Particulate}} / f_{\text{OC}}$$

- A sediment concentration can be predicted that will cause adverse effects...
 - develop a criteria, guideline or benchmark with a level of protection corresponding to the water-only guideline.